

In Figure 2 and Table 3 the rainfall probabilities are shown as a function of wind direction and pressure height. In this arrangement the maximum probability is found with a southeast wind and pressure under 29.74 inches, giving an average of 92 per cent over the 15-year period. Southeast winds with pressure 29.84 inches or less are a better indication of rain than south winds with pressure under 29.74 inches. They are almost as

TABLE 3.—Rainfall percentages resulting from the simultaneous consideration of two meteorological elements, based on 5,386 observations at Lansing, Mich. Precipitation of trace or more within 24 hours

Other element	Pressure						
	29.74 or less	29.75-29.84	29.85-29.94	29.95-30.04	30.05-30.14	30.15-30.24	30.25 or over
Wind direction:							
North	75	56	49	35	29	42	36
Northeast	71	64	50	49	43	40	42
East	82	73	74	71	59	58	54
Southeast	92	79	75	67	67	70	60
South	76	71	66	66	69	55	54
Southwest	70	52	62	58	58	48	47
West	67	63	48	54	63	57	40
Northwest	61	44	53	49	48	36	45
Wind velocity, miles per hour:							
0-4	60	56	61	51	52	47	29
5-9	78	60	62	60	61	54	53
10-over	67	52	61	64	61	51	68

favorable a sign with pressure 29.94 inches or less as south winds with 29.74 inches or less pressure. As between forecasting rain for southeast winds or for pressure under 29.74, the average probability favors the pressure element, which gives a percentage of 73 as compared with 71 for southeast winds. Least favorable conditions for rain as shown by these figures are northerly winds with the pressure over 30.05 inches. Wind-velocity averages would seem to show a greater probability for rain with increase. Least favorable are velocities under five miles, although not in every instance. The greatest probability occurs with pressure under 29.74 inches and velocity between 5 and 9 miles. The

results are not consistent, taken as a whole, however. They also fail to agree with the conclusions drawn by Blair from results obtained at Dubuque, where it was found that the greatest probability occurred with the lightest wind movement. Comparison with Blair's figures, however, does not give a true relationship, as he

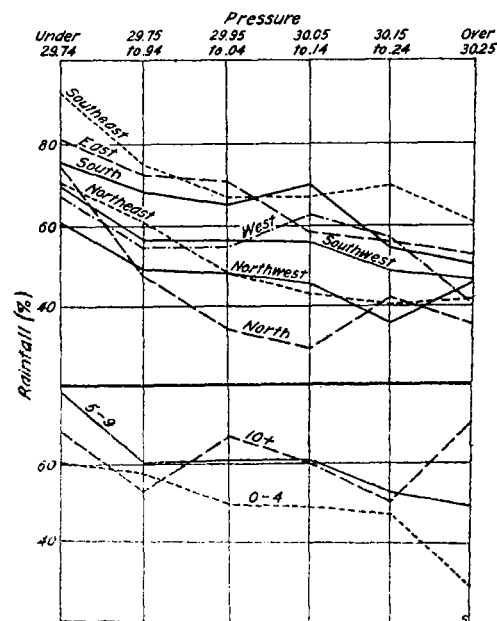


FIG. 2.—Rainfall percentages resulting from the simultaneous consideration of two meteorological elements—wind direction, wind velocity and pressure height

has considered a 24-hour rainfall period beginning with the time of the observation of the several elements or 12 hours earlier than the rain period considered in the present paper. This would seem to explain, too, the results obtained from his investigation, as it moves the time of the observed rainfall nearer to the time of the wind observation, with the accompanying more or less calm conditions of the storm's central area. Figure 2 gives a graphical story of the results described.

WIND AS MOTIVE POWER FOR ELECTRICAL GENERATORS

551.55 : 621.313

By HARRY G. CARTER

[U. S. Weather Bureau, Lincoln, Nebr.]

The main reason why wind-driven electrical generators have not come into general use for rural homes is, probably, the hesitancy of the prospective purchaser to depend upon the capricious wind. He knows in a vague way that there are periods of low wind movement and his lack of information on the subject causes him to doubt the success of a generator so operated.

In order to meet the constantly growing demand for an economical and efficient plant of this type, scientists at the College of Agriculture, University of Nebraska, have been experimenting for several years. They have found that a wind velocity of nearly 10 miles per hour is necessary to charge batteries, the wind wheel being exposed at an elevation of 60 feet. This minimum velocity agrees quite closely with the results of experiments carried on at other places.

In view of this requirement, it is interesting to know how much of the time a 10-mile wind may be expected. What per cent of the time will the wind be too light? How often do these periods of low wind movement occur? What is their average and extreme duration? During

what part of the year and of the day are they most frequent? These are vital questions, and while the data may not enable us to foretell the behavior of the wind on a definite day, a knowledge of its behavior in times past gives at least its future average values.

The writer has made a study of the Weather Bureau records of wind velocity at Lincoln for the 10 years 1912 to 1921, inclusive. The most important facts are presented in the accompanying tables and charts. By means of such data the experimenter will better understand the requirements for meeting the actual, rather than the theoretical conditions; and the prospective purchaser may intelligently judge for himself the practicability of a wind-power generating plant.

All measurements were made by a Robinson cup anemometer, the instrument adopted by the U. S. Weather Bureau for measuring wind velocity. The anemometer was exposed above the Brace Physical Laboratory Building on the city campus of the University of Nebraska at Lincoln at a height of 84 feet above the ground.

For the year as a whole a velocity of 10 or more miles per hour for at least five hours of the day occurred on 75 per cent of the days, while a velocity of 10 or more miles per hour for five or more consecutive hours each day occurred on approximately 67 per cent of the days. (See fig. 1.)

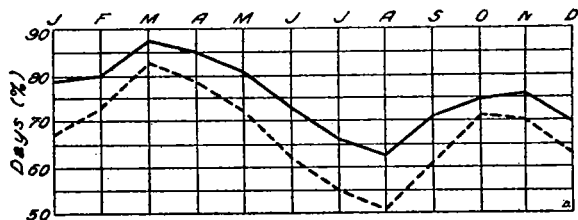


FIG. 1.—Percentage of days with wind movement equaling or exceeding 10 miles per hour for a total of five or more hours each day (unbroken line), and percentage with wind movement equaling or exceeding 10 miles per hour for five or more consecutive hours each day (broken line), for the 10 years, 1912 to 1921, inclusive, at Lincoln, Nebr.

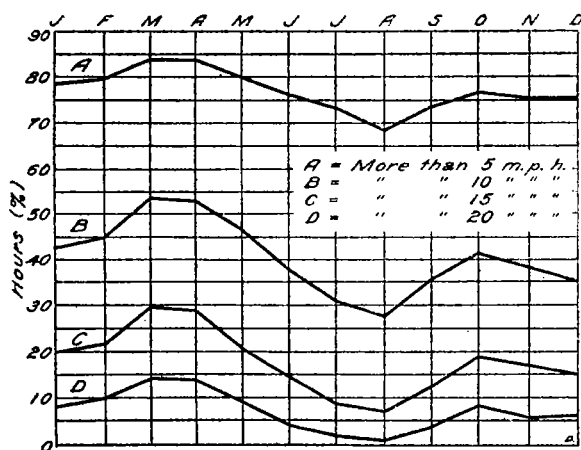


FIG. 2.—Percentage of hours with wind velocity exceeding 5, 10, 15, and 20 miles per hour for the different months, for the 10 years, 1912 to 1921, inclusive, at Lincoln, Nebr.

TABLE 1.—Percentage of hours with wind movement of stated amounts for the 10 years 1912 to 1921, inclusive, at Lincoln, Nebr.

Month	Less than 5 miles per hour	6 to 10 miles per hour	11 to 15 miles per hour	16 to 20 miles per hour	21 to 25 miles per hour	More than 25 miles per hour
January.....	Per cent 22.1	Per cent 35.2	Per cent 22.7	Per cent 11.8	Per cent 5.2	Per cent 3.0
February.....	20.4	34.7	23.0	11.9	5.3	4.7
March.....	15.7	30.5	24.2	15.2	8.6	5.8
April.....	16.0	30.8	23.9	15.3	8.6	5.4
May.....	20.5	32.9	25.2	12.9	5.2	2.3
June.....	22.6	39.6	23.1	10.6	3.1	1.0
July.....	26.2	43.1	21.9	6.7	1.8	.3
August.....	31.3	40.9	20.4	6.1	1.0	.3
September.....	25.6	38.9	23.0	9.1	3.0	.4
October.....	23.1	35.4	22.8	10.0	5.6	2.2
November.....	24.4	37.0	21.4	11.1	3.5	2.6
December.....	24.5	40.2	19.8	9.2	4.2	2.1
Yearly average....	22.7	36.6	22.6	10.9	4.6	2.6

A wind movement exceeding 5 miles was recorded during 77 per cent of the hours; exceeding 10 miles, during 41 per cent; exceeding 15 miles, 18 per cent, and exceeding

20 miles, 7 per cent. The monthly values are shown in Table 1. The same data are presented graphically in Figure 2, which probably emphasizes the change from month to month better than the numerical values in the table.

The diurnal changes in velocity for the four seasons are shown in Figure 3. The increase during the morning and early afternoon and the decrease during the late afternoon and evening are quite pronounced.

It is not necessary to charge batteries continuously; so the wind need not blow at the rate of 10 miles per hour throughout the day. Under average conditions five hours charging every two or three days would seem sufficient to keep the batteries in good condition. From the work carried on at the University of Nebraska it was found that a 16-cell 32-volt 180 ampere-hour battery would furnish current for the needs of the average home for three to five days without recharging, depending upon the amount of current consumed.

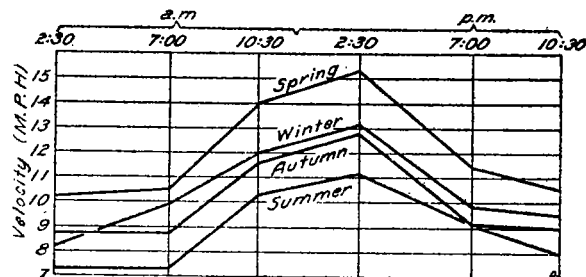


FIG. 3.—Average wind velocity for certain hours of the day for the different seasons for the 10 years, 1912 to 1921, inclusive, at Lincoln, Nebr.

Periods of from three to five consecutive days without sufficient wind to charge the batteries were not of frequent occurrence but occurred often enough to require careful consideration. (See Table 2 and 3.) They seemed to be more frequent in late summer and early winter and least frequent in spring, with a secondary minimum frequency in autumn. Periods of low wind movement exceeding five consecutive days were uncommon, averaging less than one each year, and were quite evenly distributed throughout autumn, winter, and summer, but did not occur during the spring.

TABLE 2.—Total number of periods of two or more consecutive days in which wind movement did not equal 10 miles per hour for a total of at least five hours each day, for the 10 years 1912 to 1921, inclusive, at Lincoln, Nebr.

Number of consecutive days	January	February	March	April	May	June	July	August	September	October	November	December	Total for 10 years
2	3	4	3	4	6	5	9	13	13	11	8	7	92
3	4	3	3	3	1	3	7	5	2	3	4	4	45
4	0	0	0	0	0	0	0	1	1	0	0	0	2
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	1	0	0	0	0	1

TABLE 3.—Total number of periods of two or more consecutive days in which wind movement did not equal 10 miles per hour for five or more consecutive hours each day, for the 10 years 1912 to 1921, inclusive, at Lincoln, Nebr.

Number of consecutive days	January	February	March	April	May	June	July	August	September	October	November	December	Total for 10 years
2	11	11	3	8	9	5	8	13	17	12	6	17	126
3	5	2	1	4	4	4	10	9	5	3	3	7	57
4	1	1	1	0	2	1	6	8	2	2	3	4	29
5	0	0	0	0	0	2	2	3	0	0	1	1	12
6	0	0	0	0	1	2	0	0	0	0	1	1	8
7	0	0	0	0	0	0	2	1	1	0	0	0	4
8	0	0	0	0	0	0	1	0	0	0	0	0	3
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	0	0	0	1
11	0	0	0	0	0	0	0	0	1	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	1	0	0	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	0	0	0	0	0	0	0	0	0	0	1

Since the amount of electricity used on farms depends mainly upon the amount used for lighting purposes, more electricity is consumed during the months when nights are longer, and the batteries then require more frequent charging. A comparison between the hours of

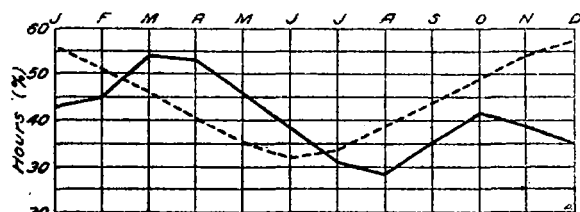


FIG. 4.—Percentage of hours with wind velocity equaling or exceeding 10 miles per hour (unbroken line), and percentage of hours of darkness (broken line), at Lincoln, Nebr., for the 10 years, 1912 to 1921, inclusive

TABLE 4.—Recorded average hourly wind movement (miles) at certain Weather Bureau stations, with height of anemometer

Station and height of anemometer	January	February	March	April	May	June	July	August	September	October	November	December	Year
Lincoln (34 feet).....	10.7	11.3	12.6	13.0	11.2	10.1	8.9	8.6	9.7	10.5	10.4	10.2	10.6
North Platte (51 feet).....	7.6	8.1	9.5	10.4	9.1	8.1	7.2	6.3	7.5	7.8	7.8	7.4	8.1
Omaha (122 feet).....	9.1	9.7	10.1	10.1	8.9	7.8	6.9	6.7	7.5	8.2	8.6	8.7	8.5
Sioux City, Iowa (164 feet).....	12.3	12.7	13.6	14.6	13.2	11.8	10.1	9.9	11.4	12.2	11.9	11.6	12.1
Valentine (54 feet).....	9.8	9.8	11.3	12.4	11.6	10.7	9.7	9.1	10.0	10.2	9.7	9.5	10.3

CLIMATOLOGICAL DATA FOR ANDAGOYA, REPUBLIC OF COLOMBIA, SOUTH AMERICA

551.58 (86)

By P. C. DAY

[Weather Bureau, Washington, D. C., Aug., 1926]

Through the courtesy of Mr. E. H. Westlake, vice president, Pacific Metals Corporation, 61 Broadway, New York, N. Y., the Weather Bureau has received regularly for a number of years, copies of the monthly meteorological records made at the mining camp of that corporation at Andagoya, located on the San Juan River in the northwestern part of Colombia, South America. The geographic coordinates of the place of observation are, latitude 5° 4' north, longitude 76° 55' west, in the Choco district, at the junction of the San Juan and Condoto Rivers, and about 250 feet above sea level.

On the west the distance in a direct line to the Pacific is about 35 miles, while to the east lie the Western Cordillera of the Andes at a distance of about 50 miles. These mountains are from 4,000 to 5,000 feet above sea level.

darkness and the wind movement is given in Figure 4. Darkness is considered as beginning one-half hour after sunset and ending one-half hour before sunrise.

The average wind velocity at the regular Weather Bureau stations in Nebraska and also at the neighboring station at Sioux City, Iowa, is shown in Table 4. The height of the anemometer at each station is shown. Since wind velocity increases with increase in elevation, the height of the anemometer should always be considered when comparing records from different stations.

In order to give a better comparison of the wind movement at the different weather bureau stations the averages were reduced to a common level. As the windmill at the Agricultural College at the University of Nebraska is 60 feet high the averages were reduced to this level. The formula used in making the reductions was suggested by Stevenson in the Journal of the Scottish Meteorological Society in 1880:

$$V = v \sqrt{\frac{H+72}{h+72}}$$

in which V is the computed velocity for the level H , in terms of the known velocity v , at the known height h .

These computed velocities are given in Table 5. While there may be a small error, they undoubtedly give a better indication of the variation in wind movement over the State than the actual averages in Table 4.

TABLE 5.—Computed average hourly wind movement (miles) at stations given in table 4, reduced to an elevation of 60 feet

Station	January	February	March	April	May	June	July	August	September	October	November	December	Year
Lincoln.....	9.8	10.4	11.6	12.0	10.3	9.3	8.2	7.9	8.9	9.7	9.6	9.4	9.8
North Platte.....	7.9	8.4	9.9	10.8	9.5	8.4	7.5	7.1	7.9	8.1	7.7	7.7	8.4
Omaha.....	7.6	8.1	8.4	8.4	7.4	6.5	5.7	5.6	6.2	6.9	7.1	7.2	7.1
Sioux City, Iowa.....	9.2	9.5	10.2	11.0	9.9	8.8	7.6	7.5	8.6	9.2	8.9	8.7	9.1
Valentine.....	10.0	10.1	11.5	12.6	11.8	10.9	9.9	9.3	10.2	10.4	9.9	9.7	10.6

In conclusion it may be said that while the data presented may not prove the feasibility of operating electrical generators by wind power, they at least show the possibilities. It would seem that here is a fruitful field for further investigations. The day may not be far distant when hundreds of rural homes will have wind power plants for generating electricity.

Between the San Juan River and the Pacific coast lies a range of hills not over 300 feet above sea level.

The instrumental equipment consists of maximum and minimum thermometers, raingage, and hygrometer, all of standard make and properly exposed. The thermometers are read daily and the precipitation is measured twice daily, 7 a. m. and 7 p. m.; local sun time.

Observations of rainfall began in August, 1914, and of temperature in September, 1917. A short record of relative humidity was made during portions of 1917 and 1919.

In addition to the above a record of precipitation covering about three years was furnished by the same company from a branch camp at Buena Vista, about 25 miles north of the main camp at Andagoya.